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EARTH SCIENCE RESEARCH

2nd QUARTERLY PROGRESS REPORT

Contract No. NSR 05-264-002

January, 1967

STUDY OF SHAPE AND INTERNAL STRUCTURE OF MOON, UTILIZING LUNAR ORBITER DATA

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LUNAR ORBITER PROGRAM OFFICE

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LETTER OF TRANSMITTAL

Office of Grants and Research Contracts
National Aeronautics and Space Administration
Washington, D.C. 20546

Attention: NASA Technical Reports Officer, Code SC

Subject: 2nd Quarterly Progress Report
Contract No. NSR 05-264-002

Gentlemen:

Earth Science Research Corporation (ESR) is pleased to submit its 2nd quarterly progress report of a study of the shape and internal structure of the Moon utilizing data from the Lunar Orbiter Program under NASA Contract No. NSR 05-264-002.

It was found that the $J_{3,0}$ term determined from study of Orbiter I has the opposite sign of the value which we would have predicted from the continent-maria distribution. Work is continuing on expanding an existing computer program to include the higher order terms in a continentality function for the Moon corresponding to the terms in the gravity field expected from analysis of the orbiter data. A review of previous studies of the shape of the Moon is continuing.

Drs. Donald L. Lamar and Paul M. Merifield discussed the relationship between the gross topographic and geologic features and the Moon's gravity field with members of the Astrogeology Branch of the U.S. Geological Survey in Menlo Park, California.

Very truly yours,

EARTH SCIENCE RESEARCH CORPORATION

Donald L. Lamar

Donald L. Lamar
Principal Investigator

RELATIONSHIP BETWEEN CONTINENT-MARIA DISTRIBUTION AND GRAVITY FIELD

Results:

In our first progress report (Earth Science Research Corp., 1966) it was shown that the effect of the distribution of continents on the $J_{3,0}$ ($J_{3,0} = -C_{3,0}$) term of the Moon's gravitational field will range from about -10.0×10^{-5} for a homogenous Moon with no isostatic compensation to -0.3×10^{-5} for isostatic compensation of continental highlands at a depth of 20.0 km. The higher value is equal to that reported by Michael, Tolson and Gapcynski (1966). It is of interest that the effect of the distribution of continents on the $J_{3,0}$ term is the same sign as the $J_{3,0}$ term derived from the study of Orbiter I. In contrast, comparison of the continental distribution with the Moon's principal moments of inertia (related to second order terms in gravity field) lead to the conclusion that density variations within the Moon are required to offset the effects of the distribution of continents (Lamar and McGann, 1966). The signs of the second order terms are fixed by the Moon's apparently stable orientation in space, and future analyses of orbiter data may provide more accurate values for the second order terms, although the signs should be the same as that derived from studies of the Moon's physical librations.

The orbiter photographs have verified that the backside is largely continental rather than maria (personal communication, Dr. Donald Wilhelms, Astrogeology Branch, U.S. Geological Survey, 1966). Nash (1963) has suggested that the maria are underlain with material denser than beneath continents and that the Moon was locked into synchronous rotation with this excess mass facing the Earth. This is consistent with our suggestion (Lamar and McGann, 1966) that the maria are underlain by denser material as an explanation for the relationship between the second order terms in a lunar continentality function and similar terms in the Moon's gravity field. Nash suggests that the maria formed as the result of impact of objects denser than the Moon and that the apparent concentration of maria in the plane of the ecliptic may be explained by an asteroidal origin for the impacting objects. Actually any process of maria formation which is random and which leads to an excess of mass beneath the maria surface could lead to the present distribution of maria with respect to the Moon's principal axes and the direction to the Earth. The present distribution may be the result of wander of the Moon's axes to the position of stable equilibrium regardless of the original cause of the density distribution.

The value of the $J_{3,0}$ term derived from analysis of the orbiter data may be explained by the distribution of continents and a spherically symmetrical mass distribution, while the second order terms and the absence of maria on the backside suggests a density distribution which departs from spherical symmetry such that the material beneath the maria is denser than that beneath the continents. Thus <u>we would have predicted the wrong sign</u> for the $J_{3,0}$ term based on our determination of the mass distribution required to produce the relationship between the second order terms and the distribution of continents. It is concluded that the mass distribution within the Moon is complex and assumptions of homogeneity, spherical symmetry or systematic density variations with respect to continents and maria are false.

Work in Progress:

Work is continuing to modify the existing computer program to include the higher order terms in the lunar continentality function corresponding to the terms to be determined in the gravitational field. These will be utilized to determine the relationship between the gravity field and distribution of continents and the nature of density variations within the Moon.

We are reviewing data on the relative ages of the individual maria and are considering the possibility that the magnitude of a density anomaly beneath a given maria is a function of its age. Such a model would be consistent with an abrupt origin for the maria and a gradual return to homogeneity through interal readjustments. It is planned to make the computer program sufficiently flexible so that this and other complex density distributions may be compared with the gravity field.

SHAPE OF MOON

Work in Progress:

We are continuing our review of existing data on the shape of the Moon with particular emphasis on the origin of coordinates. The relationship between the center of figure and center of mass is fundamental to any study of the internal structure of the Moon utilizing data on the gravity field. This problem is also of practical significance, because if the exploration of the Moon proceeds to the point where geophysical and astronomical observations are taken from points on the surface, it will be desirable to use the center of mass as the origin of coordinates for lunar maps, rather than the center of figure as is now the case.

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